IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MASSACHUSETTS

THE HOLMES GROUP, INC., Plaintiff, vs. WEST BEND HOUSEWWARES, LLC and FOCUS PRODUCTS GROUP, LLC, Defendants.	Civil Action No. 05-CV-11367 WGY (Alexander, M.J.)

DECLARATION OF COOPER C. WOODRING
IN SUPPORT OF WEST BEND'S OPPOSITION TO
HOLMES' MOTION FOR SUMMARY JUDGMENT OF
NONINFRINGEMENT OF WEST BEND'S DESIGN PATENTS

I, Cooper C. Woodring, hereby declare as follows:

1. I have prepared an expert report dated November 3, 2006 in this matter which was previously filed with the Court on December 1, 2006 in connection with West Bend's Design Patent Claim Construction Brief. My background is fully described therein, and a copy of my C.V. also is included.

2. I have also prepared a rebuttal expert report dated November 20, 2006 that has been provided to opposing counsel. A copy of my rebuttal report is attached hereto as Exhibit 1.

3. In forming my opinions in this matter, I have reviewed U.S. Design Patent Nos. D444,664, D444,993, and D434,266 (referred to herein as the '664, '993, and '266 patents, respectively and collectively as the "WB design patents"), the references cited during prosecution of the WB design patents, and other information identified in my reports. I have also reviewed the deposition transcripts of William Dobson and Scott Pollnow and Holmes' brief related to the WB design patents. I also examined physical samples of some of the Holmes'

products at issue in this matter and reviewed photographs of the other Holmes' products at issue in this matter.

4. Holmes' proposed claim constructions focus upon the specific configuration of the slope on the insert's lip rather than the overall visual impression created by the thinning of the lip around its entire perimeter. Holmes likewise describes the knob, which an ordinary observer would perceive as mushroom shaped, in terms of each individual surface and the precise geometry of surface edges, which an ordinary observer would not notice. Holmes' proposed construction for the '993 patent also ignores the skirt on the lid altogether.

5. As evident from Figs. 1 and 6 from WB's patents, the shape of the heating and cooking units is oval, and not a rounded off rectangle. The West Bend design does not have four corner edges or relatively small arcs of the four corner edges and does not give the visual impression of a near rectangle with slightly bowed sides. There is no rectangle, straight sides, or corners in West Bend's design.

6. Given a slow cooker's relatively low cost, market, and channels of distribution, an ordinary observer in this case would be an everyday customer who has recently purchased a slow cooker or is considering purchasing one. Also see par. 15 of my November 3, 2006 report.

7. A comparison of all figures from each of West Bend's design patents to the Holmes' accused products demonstrates that the accused products are substantially similar to the claimed design of WB's patents in the eyes of an ordinary observer.

Fig 1

Representative Sample of Rival's Accused Design with Knob, Perspective View

Representative Sample of Rival's Accused Design with Loop, Perspective Vie

Figure 1 from the '993 patent is a logical starting part for comparing the claimed design to the accused products. Neither Holmes nor its expert compares any of the accused products with Fig. 1 of the '993 patent.

The accused products appear nearly identical, and unquestionably substantially similar, to Fig. 1. An ordinary observer would thus conclude that Fig. 1 from the ‘993 patent is substantially similar to the Holmes accused products. Also see par. 32 of my November 3, 2006 report.

8. An ordinary observer would likewise conclude that Fig. 1 from both the ‘266 and ‘664 patents also are substantially similar to Holmes’ accused products. In addition to the design features of the ‘933 patent, the ‘266 patent further claims a thin band around its bottom perimeter and an opaque round shaped, disc-like (somewhat mushroom shaped) knob mounted on a round shaped smaller diameter pedestal, which are both present in the Holmes’ model nos. 3730W, 37351C, 3735W, 3752SM, 5070TCW, 5445BCN, 6445BC, SCV450SS, and SCV500SM.

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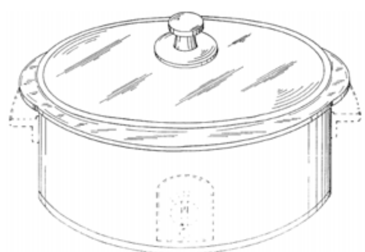

Fig. 1

9. A comparison of Fig. 6 from the '993 patent and two representative samples of Holmes' accused cookers below readily shows that in the eye of an ordinary observer, the claimed design and the accused products are substantially similar. Also see par. 38 of my November 3, 2006 report.

Fig. 6 of Patented Design

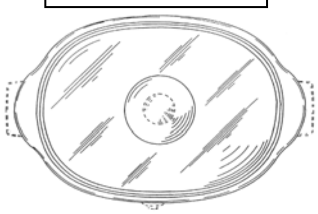

Fig. 6

Holmes' Design

Representative Sample of Rival's Accused Design with Knob, Top View

Representative Sample of Rival's Accused Design with Loop, Top View

10. Both the designs of the WB design patents and accused products are oval or elliptical in shape with inserts, i.e., the cooking vessel, that have outwardly flared handles on both right and left ends with a slight "ogee" or reverse curve between the handle itself and the perimeter of the generally oval shaped insert. Both the claimed designs of the WB design patents and accused products also include an opaque skirt sitting atop the transparent domed lid, the skirt being larger in diameter than the knob handle (the knob is not claimed in the '993 patent). Also see par. 38 of my November 3, 2006 report. The insert, or cooking vessel, lip of the patented designs and accused products have an edge that thins around the insert's entire perimeter, which further buttresses the conclusion that an ordinary observer would view the overall designs as substantially similar. Also see par. 34 of my November 3, 2006 report.

Fig. 4 of Patented Design

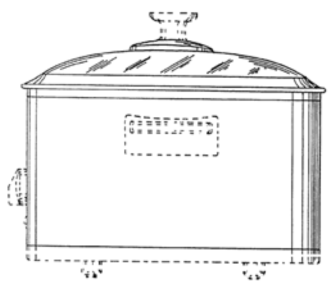

Fig. 4

Holmes' Design

Representative Sample of Rival's Accused Design with Knob, Right Side View

Representative Sample of Rival's Accused Design with Loop, Right Side View

11. Referring to the above comparisons of Figs. 1 and 4 of the '993 patent, an ordinary observer would conclude that the skirts of the claimed design and accused products are substantially similar. Additionally, the bottom view of the claimed designs (Fig. 7) and the accused products also

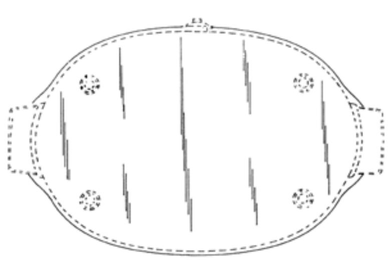

Fig. 7

would be perceived as substantially similar in the eye of the ordinary observer. While the accused products have fastening devices, holes, and stamped depressions to add structural integrity to the flat bottom surface, these features are functional. As to the ‘664 patent that includes four feet (the ‘993 and ‘266 patents do not claim the feet), a comparison of Fig. 7 with a representative sample of the accused Holmes cookers demonstrates that the overall appearance of the patented design and accused products would be substantially similar despite the minor differences in the appearance of feet on the accused products. Also see par. 39 of my November 3, 2006 report.

12. The inventors of the WB design patents are not “ordinary observers.” They are intimately familiar with the details of their designs, and thus would perceive minor differences in shape that would not be apparent to an ordinary observer.

13. Mr. Mauro’s “invariant feature analysis” has no relationship whatsoever to how ordinary consumers observe or compare product designs. In fact, Mr.Mauro’s use of this method of analysis proves the substantial sameness of the patented and accused designs as invariant feature analysis is only employed when a human cannot accurately distinguish between designs, or when there are endless design comparisons to be made to find a match. For example, a fighter pilot sees a tank and wants to kill it, but is uncertain if it’s friendly or an enemy, as all tanks look alike from a fighter pilot’s distance and speed. So, sophisticated computerized invariant feature analysis systems are employed to compare hundreds of details of that particular tank’s shape against a data base of known tank designs to confirm that it is, or is not, an enemy tank. This sophisticated computer analyzed invariant feature analysis is a far cry from how an ordinary observer shops for a slow cooker at WalMart. See Exhibit 2 for a synopsis of Princeton’s “Shape Retrieval and Analysis,” see Exhibit 3 for a synopsis of U. of California’s “Image Database

Indexing Using a Combination of Invariant Shape and Color Descriptions for Military Aircraft Identification," and see Exhibit 4 for a synopsis of the U.S. Navy¹s "Robust Airborne Combat Identification Using Scale Invariant Spatial and Spectral Electro-Optic Signatures."

14. Mr. Mauro's "invariant feature analysis" is also the methodology utilized in identifying people by "facial recognition" by analyzing the highly detailed invariant facial features compared to millions of photographs of other people's faces to find a match. While two faces may appear substantially similar to an ordinary observer, the use of invariant feature analysis reveals differences in the facial features to ensure that that faces are correctly matched. This has been made possible in recent years as driver's license and passport photographs have become digitized. Kentucky alone contributes 4,000 facial images to the database every day and has contributed 3,900,000 since 2002. Those 3.9 million photographs can be scanned for an invariant feature match in about 15 seconds with 99.9% accuracy (see Exhibit 5 for "New Facial Recognition Software Fights Identity Fraud"). Invariant feature analysis is not a method ordinary observers employ to compare and select a product at the point of purchase.

15. An ordinary observer would not decompose the shape of the claimed designs and accused products to perceive the supposed differences identified by Holmes' "invariant feature analysis." Holmes' expert's reliance on highly technical invariant shape analysis to determine that there is a minor visual difference between the two generally oval shapes has absolutely nothing to do with how ordinary observers perceive everyday household, or traffic, appliances, like slow cookers. It does, however, confirm that the two generally oval shapes of the WB design patents and accused Holmes' products are so substantially similar that sophisticated computerized methods of comparison and analysis were employed by Mr. Mauro to determine that the shapes were not identical.

16. If any view of the WB design patents is dominant, it is the front perspective view of patent Fig. 1 because that is how consumers would view the product at the point of purchase, as demonstrated by Holmes' own packaging and catalog sheets which feature a front perspective view like patent Fig. 1. Indeed, the patent examiner selected Fig. 1 as being most representative and descriptive of the patented design, not Fig. 6.

17. Holmes' expert also bases his opinion on so-called orthographic scale drawings of the accused products that are inaccurate. Details regarding these inaccuracies are provided at paragraph 10 and Exhibit 2 of my Rebuttal Expert Report. Even if they were accurate, these drawings do not focus upon the overall design of West Bend's patents compared with the overall design of the accused products and instead focus upon minor details. Additionally, an ordinary observer would not resort to these orthographic scale drawings when comparing the overall design of WB's patents with Holmes' accused products.

18. Following are the points of novelty of WB's patented designs.

'993 Patent	**'266 Patent**	**'664 patent**
Lid: a translucent and oval shaped lid having no integral skirt or knob	Lid: a translucent and oval shaped lid having no integral skirt or knob	Lid: a translucent and oval shaped lid having no integral skirt or knob
Insert: an opaque and oval shaped insert separating a lid from a body having a generally oval shaped perimeter that has slight concave curves transitioning to outwardly flared end handles and having a material thickness that thins around the insert's entire perimeter	Insert: an opaque and oval shaped insert separating a lid from a body having a generally oval shaped perimeter that has slight concave curves transitioning to outwardly flared end handles and having a material thickness that thins around the insert's entire perimeter	Insert: an opaque and oval shaped insert separating a lid from a body having a generally oval shaped perimeter that has slight concave curves transitioning to outwardly flared end handles and having a material thickness that thins around the insert's entire perimeter
		Feet: four opaque small cylindrical feet placed in a rectangular pattern on the body's bottom

Details regarding my identification of these points of novelty are provided at ¶¶ 46-53 of my November 3 expert report. It is no longer my opinion that the knob and skirt of the patented designs are points of novelty because they are found in the prior art.

19. The Holmes accused products appropriate the points of novelty of WB's patents. The above comparison of Fig. 6 of WB's design patents to representative samples of Holmes' accused cookers demonstrates that the accused cookers appropriate the point of novelty relating to the translucent domed and oval-shaped lid having no integral skirt or knob.

20. Figures 1, 2, and 6 of the patents show another point of novelty appropriated by Holmes, namely, an opaque and oval shaped insert separating the lid from the cooker body with the insert having a generally oval shaped perimeter that has slight concave curves transitioning to outwardly flared end handles (shown in Fig. 6) and having a material thickness that thins around the insert's entire perimeter (shown in Fig. 2). The accused Holmes cookers thus appropriate these points of novelty of the '993, '266, and '664 patents.

Fig. 2 of Patented Design

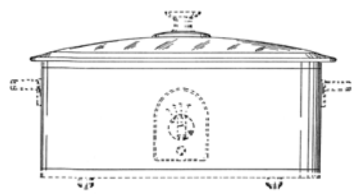

Fig. 2

Holmes' Design

Representative Sample of Rival's Accused Design with Loop, Front View

21. I disagree that "the domed lid being shaped to make a smooth transition from its outer periphery to the upper edge of the cooking vessel lip" is a point of novelty to the WB design patents as proposed by Holmes. Instead, the proper point of novelty directed to the lid of the patented designs encompasses "a translucent and oval shaped lid having no integral skirt or

knob," as identified above. Regardless, at least some of the accused cookers include such a smooth transition between the lip and lid, as shown here.

22. I also disagree that "the lip of the cooking vessel sloping from a top surface to a bottom surface downwardly and outwardly throughout is perimeter and including a slight concave shape from the top surface to the bottom surface, the bottom surface being substantially flat" is a point of novelty to the WB design patents as proposed by Holmes. Instead, the proper point of novelty directed to the insert of the patented design is "an opaque and oval shaped insert separating a lid from a body having a generally oval shaped perimeter that has slight concave curves transitioning to outwardly flared end handles and having a material thickness that thins around the insert's entire perimeter," as identified above.

I declare under penalty of perjury that the foregoing is true and correct and, as to matters stated to be alleged on information and belief, I believe them to be true.

Executed this 22nd day of December, 2006.

/s/ Cooper C. Woodring
Cooper C. Woodring, FIDSA®

EXHIBIT 1 Part 1

United States District Court
For The District of Massachusetts

West Bend Housewares, LLC
Plaintiff,

v.

Civil Action No. 05-CV-11367-WGY
(Alexander, M.J.)

The Holmes Group, Inc.
Defendant.

Rebuttal Report of Cooper C. Woodring, FIDSA®

Background

1. I submitted an Expert Report on behalf of plaintiff West Bend, dated November 3rd, 2006.

2. I have read the Expert Report of Charles L. Mauro on behalf of defendant Holmes, also dated November 3rd, 2006.

3. Mr. Mauro opines on infringement and validity and concludes that: 1. The Gorham "ordinary observer" test is not satisfied, 2. The Litton "point of novelty" test is not satisfied, and 3. West Bend's '664, '266 and '993 design patents are invalid due to obviousness. I disagree with all three of Mr. Mauro's conclusions and will address them in order.

The Gorham "Ordinary Observer" Test - Discussion

4. The correct standard for comparison under the Gorham ordinary observer test is further clarified in OddzOn Prods., Inc. v. Just Toys, Ind. 22F.3d 1396, 1405, 43 USPQ2d 1641, 1647 (Fed. Cir. 1997),

> "What is controlling is the appearance of the <u>design as a whole</u> in comparison to the accused product" (underline added).

5. Mr. Mauro's analysis under the Gorham test is not based on the appearance of the "design as a whole", but is based on a comparison of the top view, which he calls "the dominant shape". Mr. Mauro's "invariant feature" comparison of "the dominant shape" is the kind of narrow comparison the Gorham test seeks to avoid, as it does not focus on the "design as a whole". Any design expert, including me, would acknowledge that the generally elliptical shape of West Bend's design and the generally elliptical shape of Rival's design are slightly different. The Gorham test is not a question of whether the two generally elliptical shapes are substantially the same, which they are, the question is whether the patented and

accused "designs as a whole" are substantially the same, which they are.

6. Regarding this minor difference between the two generally elliptical shapes, Mr. Mauro concludes that, "This results in a fundamentally different dominant shape . . . . . ". I disagree. The two designs are fundamentally the same shape, with minor differences that would probably remain unnoticed by the ordinary observer. I had previously qualified the ordinary observer in this case as an "everyday customer". Mr. Mauro did not identify the ordinary observer in order to establish some appropriate level of scrutiny.

7. While there are no portions of a claimed design that are immaterial or unimportant, Mr. Mauro focuses his Gorham test analysis on what he calls the "dominant shape", namely Figure 6 of West Bend's patents, or the top view. Mr. Mauro explains his choice: "This is a test of the first impression of objects and is consistent with how individuals, including those in retail settings, commonly view objects". I disagree. If Mr. Mauro is correct that consumers see slow cookers from the top view in retail settings, the slow cookers would be displayed on the floor so that we would look down at their top views, which they are not.

8. While I disagree with Mr. Mauro's "dominant view" theory altogether, however if any view is dominant it is the front perspective view, as shown in Figure 1 of West Bend's patents. This front perspective view is how consumers see slow cookers at the point of purchase and on their own kitchen countertops. The front face of Rival's own packaging shows the Crock Pot in the front perspective view, not the top view. Moreover, Examiner Veynar selected Figure 1, the front perspective view, as being most descriptive of West Bend's design and included it on the face of West Bend's patents.

9. At the bottom of Page 13, Mr. Mauro explains: "Figure 1, from the patent was not included is (sic) this report since it was not possible to produce a suitable underlying photograph of the accused Holmes products". Please see Exhibit 1 to this report. I found it possible to produce suitable photographs of the accused Holmes products in this view and I also found it possible to eliminate from the photographs portions that were not claimed in West Bend's '993 patent to make the comparison proper and accurate. When reviewing the overall appearance of the patented and accused designs shown in Exhibit 1, it would be almost impossible to conclude that to an ordinary observer the two designs "result in fundamentally different dominant shapes". The shapes are practically indistinguishable.

10. In design patent litigation, the proper comparison is the design patent's drawings compared to the actual accused device. For convenience, photographs of the accused device are often substituted. Mr. Mauro's analysis relies on drawings that he made up of the accused designs for comparison. He explains the purpose of his drawings (near the center of Page 12) "is to decompose the visually salient elements of each design into primitive shapes". First, all the elements of a design are "visually salient elements" and all elements of a design are material and important. There is no hierarchy that says this visual element is more important than that one and therefore should be given more weight. Second, even if there were, we must view the visual elements as they are, not as Mr. Mauro has translated them into

"primitive shapes". And, finally, Mr. Mauro's drawings are just plain inaccurate and wrong. As an example, Exhibit 2 contains a reproduction of Mr. Mauro's drawing from Page 14 of his report and a corresponding photograph of what Rival's 37351 Crock Pot really looks like. Mr. Mauro's drawing shows the vent hole in the lid in the wrong location (it must be on the lid's horizon); it shows the lid's lower edge as being exposed, when it is actually hidden well below the upper rim of the insert; it shows no concave underside to the insert's outwardly flared handles; the thin band around the body's upper perimeter is disproportionately wide; the body's handles are not claimed in West Bend's patents and should not have been shown in solid lines for comparison; the controls are also not claimed and should not have been shown in solid lines; the thin band around the body's lower perimeter should be raised from the body's surface like the top band, but is not; it shows no angle or slant around the body's bottom perimeter; and, the feet are wrong, they belong on the 3730 Crock Pot, not the 37351. Each of these errors can be seen by comparing Mr. Mauro's drawing with the photograph of the 37351 Crock Pot shown in Exhibit 2.

11. The Gorham "ordinary observer" test also requires comparing the ornamental features of the patented design to the accused products' overall or whole design. The Gorham test is not limited to comparing only the patented design's points of novelty to the accused design. That comes later during the Litton test. At the top of Page 8, Mr. Mauro states: "The purpose of this initial process was to create a meaningful, point by point detailed comparison of the alleged points of novelty and the actual accused products in this litigation". Comparing only the points of novelty is also not the proper standard for the Gorham test as it would, for example, eliminate the body from comparison, as the body is not included in the points of novelty.

The Gorham "Ordinary Observer" Test - Conclusion

12. Mr. Mauro's opinions are based on having utilized the wrong standards combined with flawed analysis and inaccurate drawings. His conclusions, therefore, should be disregarded.

The Litton "Points of Novelty" Test - Discussion

13. Mr. Mauro's states that West Bend's points of novelty are not valid and are not present in Rival's accused designs. He offers no specific prior art to support his opinion and he states no reason why the points of novelty are not present in the accused Rival designs.

The Litton "Points of Novelty" Test - Conclusion

14. Mr. Mauro's opinions and conclusions are unsupported and are therefore without merit.

35 U.S.C. §103 Obviousness - Discussion

15. Mr. Mauro states that West Bend's design patents are invalid due to obviousness.

16. 35 U.S.C. §103 states that an invention is not patentable:

> "if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains."

17. Mr. Mauro relies on three prior art design patents, the D429,596 (the '596 patent), the D420,246 (the '246 patent), and the D416,434 (the '434 patent) for support of his opinion of obviousness. Examiner Caron D. Veynar examined the three prior art design patents. She also examined the three West Bend patents in suit. Examiner Veynar determined that the West Bend patents in suit were not obvious in light of the same three prior art patents relied on by Mr. Mauro.

18. I have been advised by counsel that Rival's and West Bend's catalog sheets relied upon by Mr. Mauro have not been established as prior art. Nonetheless, I will treat them as prior art, except for WB000080 & 81, to demonstrate that they do not contain the points of novelty of West Bend's design patents. The WB000080 & 81 catalog sheets will not be included in the comparison as I have been advised by counsel that they are not prior art.

19. Exhibit 3 contains a grid comparing the alleged prior art patents and catalog sheets cited by Mr. Mauro and West Bend's patents' points of novelty. This grid demonstrates that the references relied upon by Mr. Mauro do not contain any of West Bend's patents' points of novelty.

35 U.S.C. §103 Obviousness - Conclusion

20. The references relied upon by Mr. Mauro that are prior art do not make obvious West Bend's patents in suit. The references that have not been established as prior art cannot be relied upon in an obviousness defense.

21. Obviousness also requires some suggestion or motivation to combine prior art in a way that might arrive at the patented design. Mr. Mauro cites none and I found none. Even if there were a suggestion or motivation to combine prior art, the combination would not result in the design of the patents in suit as demonstrated by the grid in Exhibit 3.

Statements

22. In compliance with Federal Rule of Evidence 702, my opinion is based upon sufficient facts or

data, it is the product of reliable principles and methods, and I have applied the principles and methods reliably to the facts in this case.

23. I am fully familiar with the facts in this Expert Report and they are based upon my own personal knowledge.

24. Pursuant to 28 U.S.C. § 1746, I declare under penalty of perjury that the foregoing is true and correct.

Respectfully Submitted,

Cooper C. Woodring

Cooper C. Woodring, FIDSA®

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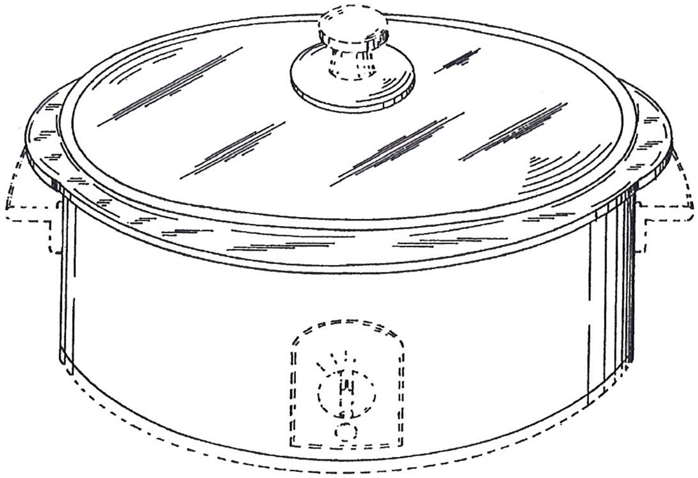
Monday 20 November 2006

EXHIBIT 1 Part 2

Exhibit 1

West Bend's '993 Design Patent, Fig. 1



Rival's 3730 Accused Design

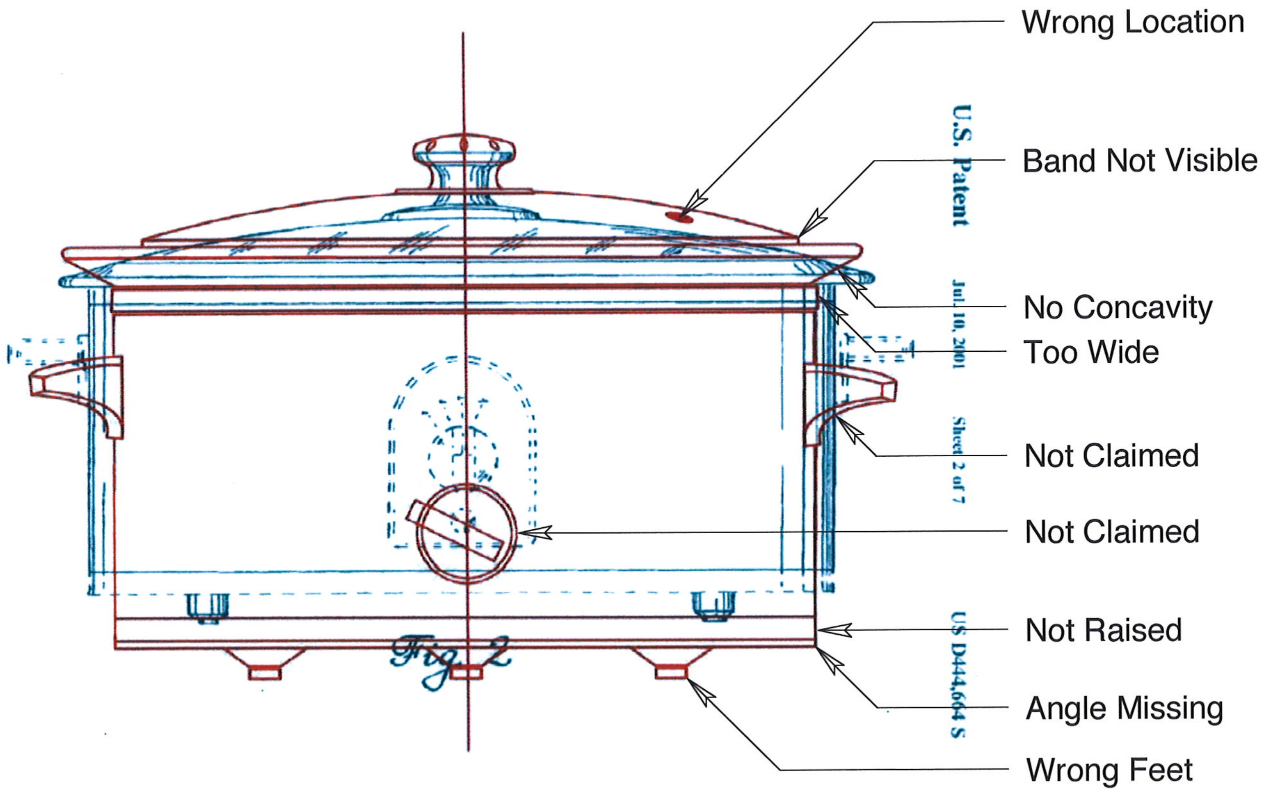
Rival's 37351 Accused Design

EXHIBIT 1 Part 3

Exhibit 2

Mauro's Drawing of the Accused 37351 Design (in Red)

The Holmes product 37351 vs. '664 patent figure analysis



A Photograph of the Accused 37351 Design

EXHIBIT 1 Part 4

Exhibit 3

The Ornamental Points of Novelty

The Patents	Knob	Skirt	Lid	Insert	Feet
	An opaque round shaped and disc-like knob mounted on a round shaped smaller diameter pedestal, or a somewhat mushroom shaped knob.	An opaque round shaped and disc-like skirt that is larger in diameter than the knob.	A translucent domed and oval shaped lid having no integral skirt or knob.	An opaque and oval shaped insert separating a lid from a body having a generally oval shaped perimeter that has slight concave curves transitioning to outwardly flaired end handles and having a material thickness that thins around the insert's entire perimeter.	Four opaque small cylindrical feet placed in a rectangular pattern on the body's bottom.
West Bend's '664 Patent Claims: Knob, Skirt, Lid, Insert, Body and Feet	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
West Bend's '266 Patent Claims: Knob, Skirt, Lid, Insert and Body	**Yes**	**Yes**	**Yes**	**Yes**	No, feet not claimed
West Bend's '993 Patent Claims: Skirt, Lid, Insert and Body	No, knob not claimed	**Yes**	**Yes**	**Yes**	No, feet not claimed

The Prior Art References Relied Upon by Mr. Mauro

Hlava et al's D429,596 Design Patent for a "Slow Cooker"	No, the knob is translucent and it is not round	No, it has no skirt	No, the lid is not oval	No, the insert is not gererally oval	No, it has three large tapered feet
Alonge et al's D420,246 Design Patent for a "Slow Cooker"	No, the knob is translucent	No, the skirt is translucent	No, it has an integral skirt and knob	No, the material thickness does not thin around the entire perimeter	No, it has three large domed feet
Pollnow's D416,434 Design Patent for a "Cooker"	No, the knob and skirt are one piece	No, the knob and skirt are one piece	No, the lid is not oval	No, the insert is round	No, it has three small round feet
THG000030062 & 63 are Rival's Catalog Sheets Showing the Same Design as Hlava et al's D429,596 Design Patent Above	No, the knob is translucent and it is not round	No, it has no skirt	No, the lid is not oval	No, the insert is not gererally oval	No, it has three large tapered feet
WB000516 & 17 are West Bend's Catalog Sheets Showing the Same Design as Pollnow's D416,434 Design Patent Above	No, the knob and skirt are one piece	No, the knob and skirt are one piece	No, the lid is not oval	No, the insert is round	No, it has three small round feet
WB001165 & 66 are West Bend's Catalog Sheets Showing the Same Design as Pollnow's D416,434 Design Patent Above	No, the knob and skirt are one piece	No, the knob and skirt are one piece	No, the lid is not oval	No, the insert is round	No, it has three small round feet

EXHIBIT 2

Princeton Shape Retrieval and Analysis Group

3D Search Engine | People | Overview | Shape Representations | Query Interfaces | Benchmark | Publications | Movies

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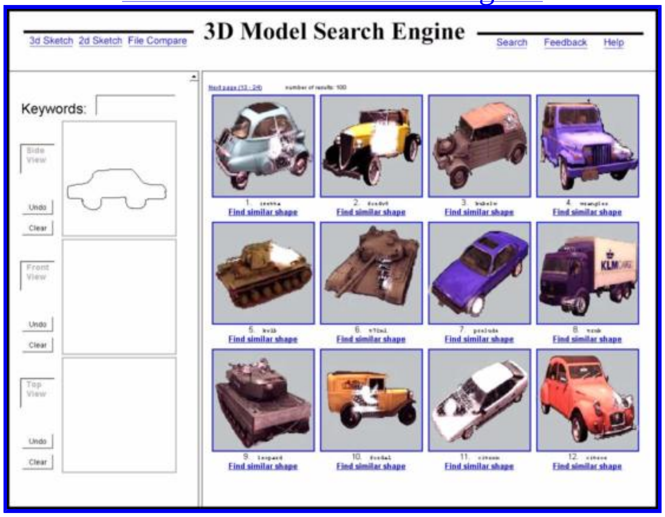
People

- Faculty
  - Bernard Chazelle
  - David Dobkin
  - Tom Funkhouser
  - Adam Finkelstein
  - Szymon Rusinkiewicz
- Graduate Students
  - Alex Golovinskiy
  - Misha Kazhdan
  - Josh Podolak
  - Patrick Min
  - Phil Shilane
  - Robert Osada
- Undergraduate Students
  - Wilkie Kiefer
  - Joyce Chen
  - Alex Halderman

Check out our 3D search engine:



Graphics & Geometry Group, CS Department, Princeton University

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Project Overview

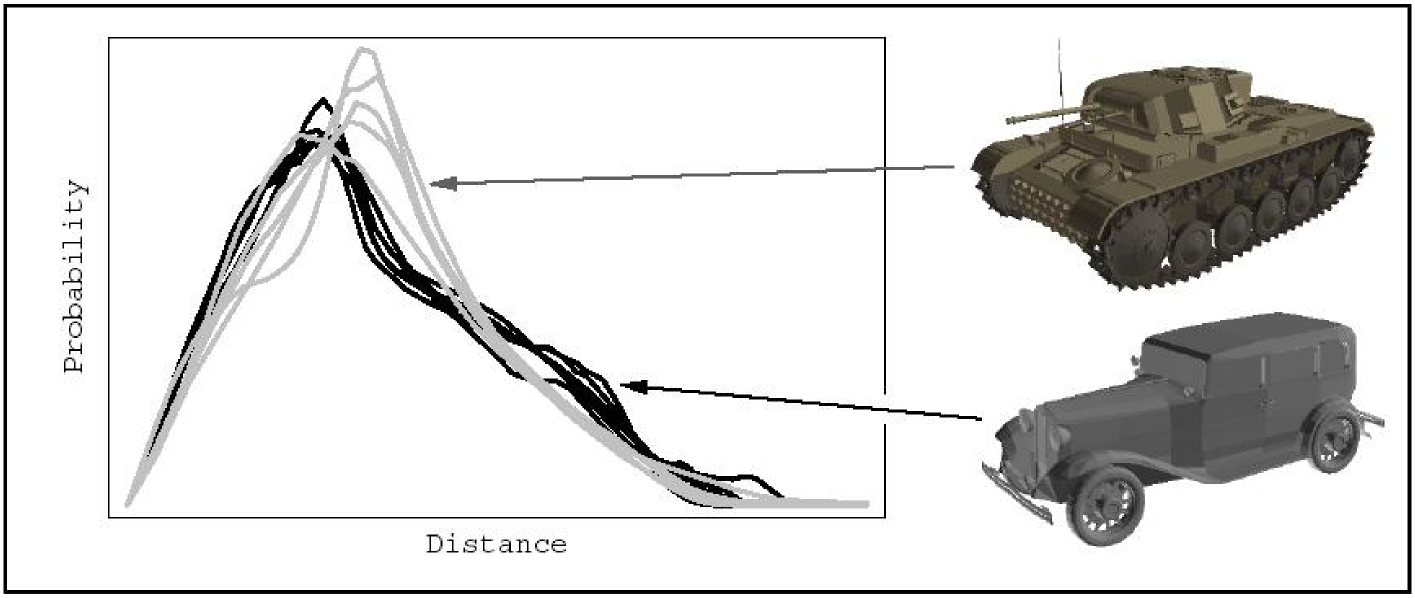
Our goal is to investigate issues in shape-based retrieval and analysis of 3D models. As a first step, we have developed a search engine for 3D polygonal models (check it out by clicking here). The main research issues are to develop effective shape representations and query interfaces. The Princeton Shape Benchmark is a set of 3D models that can be downloaded for further research. This web page provides an overview of some projects on these topics. Our publications provide more details.

Shape Representations

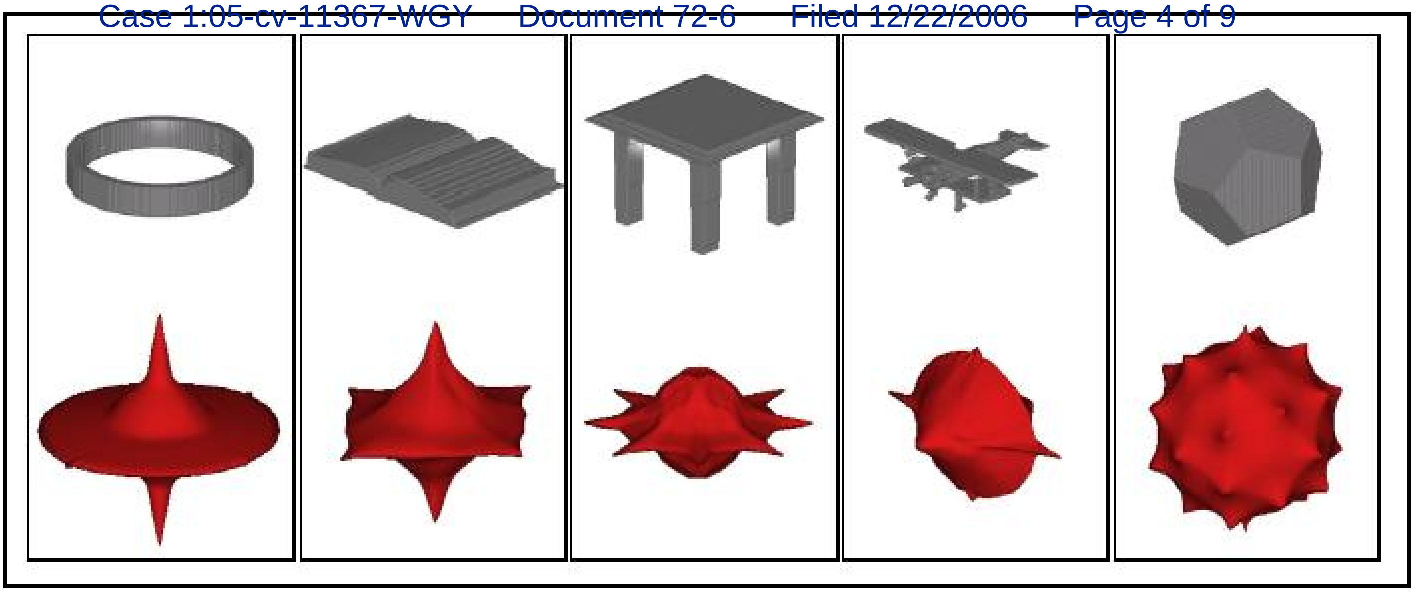
A key issue in developing a shape-based retrieval and analysis system is to find a computational representation of shape (a *shape descriptor*) for which an index can be built, similarity queries can be answered efficiently. We are studying a spectrum of shape descriptors, ranging from ones that are simple to compute (but perhaps not very discriminating) to ones that require expensive computations (but provide sophisticated shape analysis):

- **Shape Distributions:**

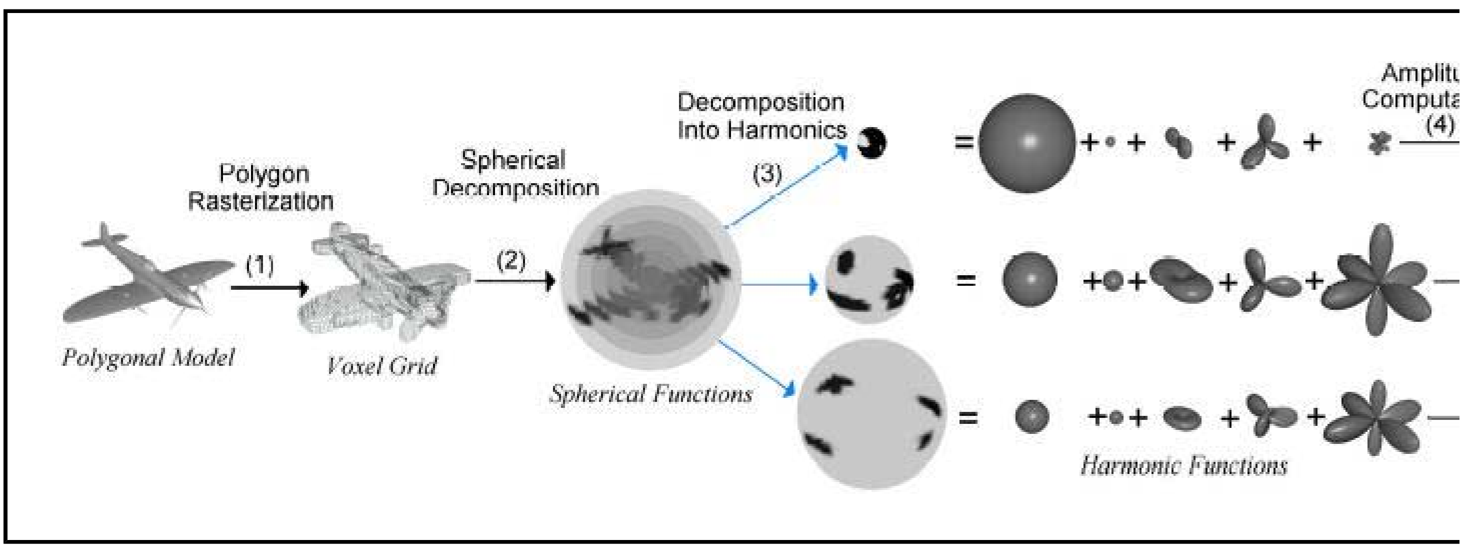
On the low end of the spectrum, we have been investigating *shape distributions* that represent the shape of a 3D model as a probability distribution sampled from a *shape function* measuring geometric properties of a 3D model. The motivation for this approach is that samples can be computed quickly and easily, and the shape of the resulting distributions are invariant to similarity transformations, noise, tessellation, cracks, etc.(with a normalization step for scale invariance). For example, one such shape distribution, which we call *D2*, represents the global shape of an object by the probability distribution of Euclidean distances between pairs of randomly selected points on its surface. The figure below shows the D2 distributions for 5 tanks (gray curves) and 6 cars (black curves). Note how the classes are distinguishable.



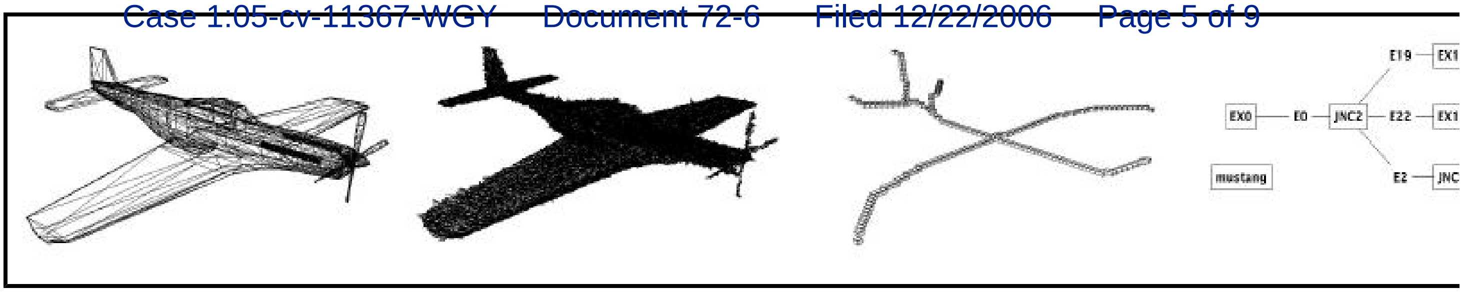
- **Reflective Symmetry Descriptors:**
  Computing reflective symmetries of 2D and 3D shapes is a classical problem in computer vision and computational geometry. Most prior work has focused on finding the main axes of symmetry, or determining that none exists. We have studied a new shape descriptor that represents a measure of reflective symmetry for an arbitrary 3D voxel model for all planes through the model's center of mass (even if they are not planes of symmetry). For example, the figure to the right shows a car, cube and chair (top) and their corresponding reflective symmetry descriptors (bottom). The descriptors are drawn by scaling unit vectors on the sphere in proportion to the measure of reflective symmetry about the plane through the center of mass and normal to the vector.The main benefits of this new shape descriptor are that it is defined over a canonical parameterization (the sphere), which makes comparison simple, and it describes global symmetry properties of a 3D shape, which capture significant semantic features of many objects.



- **Spherical Harmonics:**
One of the main challenges in matching and indexing shapes is accounting for arbitrary rotations. Previous methods that require alignment into a common coordinate system (e.g., with principal axes) are not robust. Other methods that rely upon rotationally invariant shape descriptors are usually not very discriminating. We propose a novel rotation invariant shape-descriptor based on spherical harmonics. The main idea is to decompose a 3D model into a collection of functions defined on concentric spheres and to use spherical harmonics to discard orientation information (phase) for each one. This yields a shape descriptor that is both orientation invariant and descriptive.



- **Skeletal Graphs:**
On the high end of the spectrum, we are investigating skeletons as a descriptor of shape. The general idea is to derive 1D skeletal curves from a 3D object such that each curve represents a significant part of the object. These curves are then converted to an attributed graph representation (a *skeletal graph*), which can be used for indexing, matching, segmentation, correspondence finding, etc. As an example, the figure below shows a plane model, its medial axis (as computed using the "Powercrust" algorithm [3]), our voxelized centerline representation, and the resulting skeletal graph. Note that the medial axis comprises a multitude of noisy curves and sheets, while our centerline representation nicely segments the plane into its salient parts.

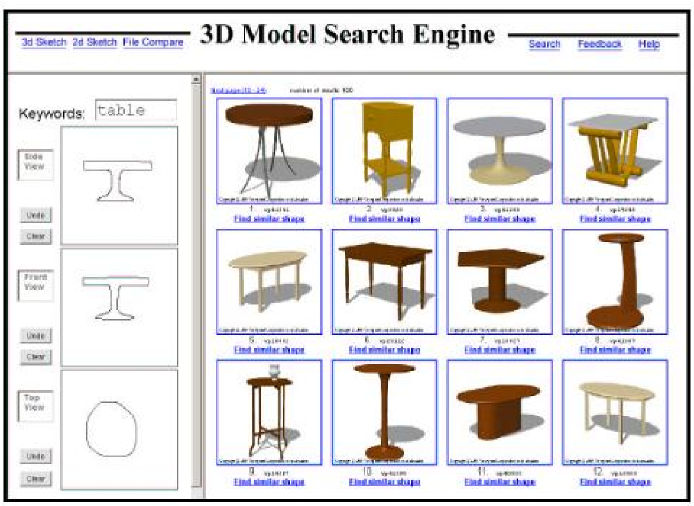


Query Interfaces

Another issue is how should people specify shape-based queries? For instance, consider a person who wants to build a 3D virtual world representing a city scene. She will need cars, street lamps, stop signs, etc. What input should be given to a search engine to retrieve objects of these types from the World Wide Web? We have investigated several options:

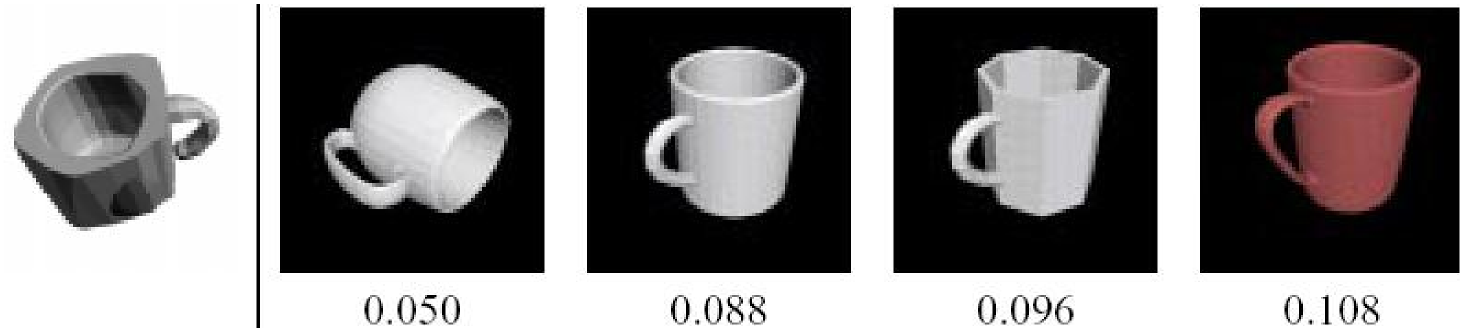
- **Text:**
  The simplest query interface is to search for 3D models based on textual keywords. To support this feature, we construct for each 3D model a representative document containing the model filename, the anchor and nearby text parsed from its referring Web page, and ASCII labels parsed from inside the model file. For each document, stop words are removed, verbs are stemmed to remove inflectional changes, and synonyms are added using WordNet [Miller95]. We match documents to user-specified keywords using the TF-IDF/Rocchio method [Rocchio71], a popular weighting and classification scheme for text documents.

- **3D Model:**
  We also support shape-based queries. For instance, the user can provide an existing 3D model and ask our search engine to retrieve similar ones. Alternately, the user may search for models with shapes like one returned in a previous search by clicking on the ``Find Similar Shape'' link under its image on a results page (blue text in the figure below).

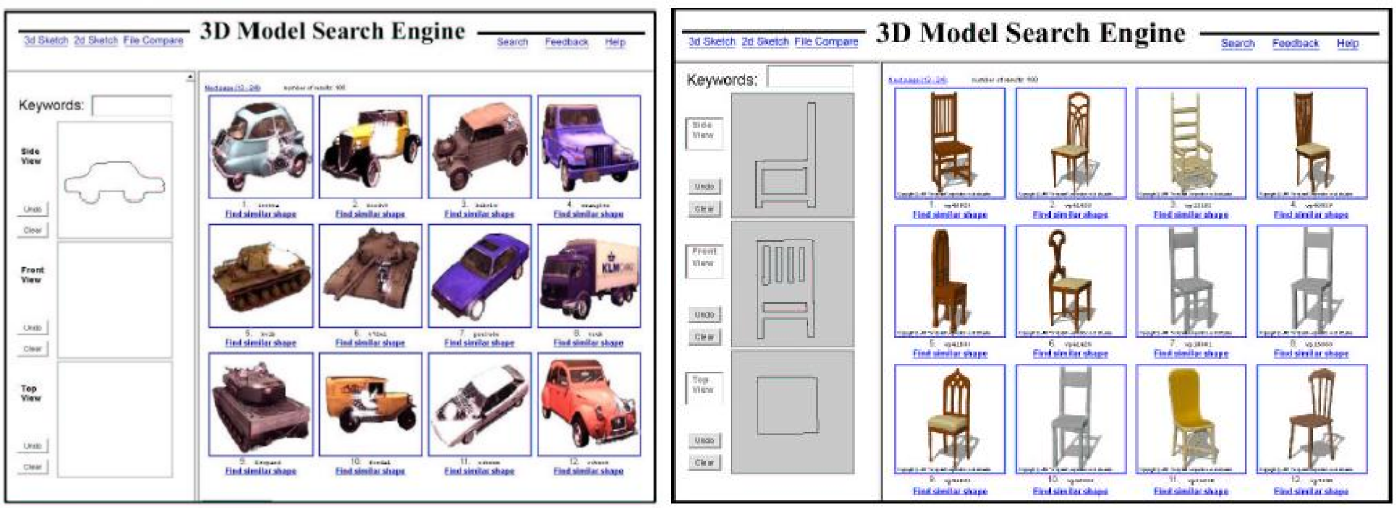


- **3D Sketches:**
  Of course, shape similarity queries are only possible when the user already has a representative 3D model. In some cases, he will be able to find one by using a text search. However, in other cases, he will have to create it from scratch (at least to seed the search). To investigate this option, we have developed a query interface in which the user creates a simple 3D model with Teddy [Igarashi99], and then the system returns objects with similar shapes. For example, the figure below shows a cup

sketched in Teddy and its five closest matches.



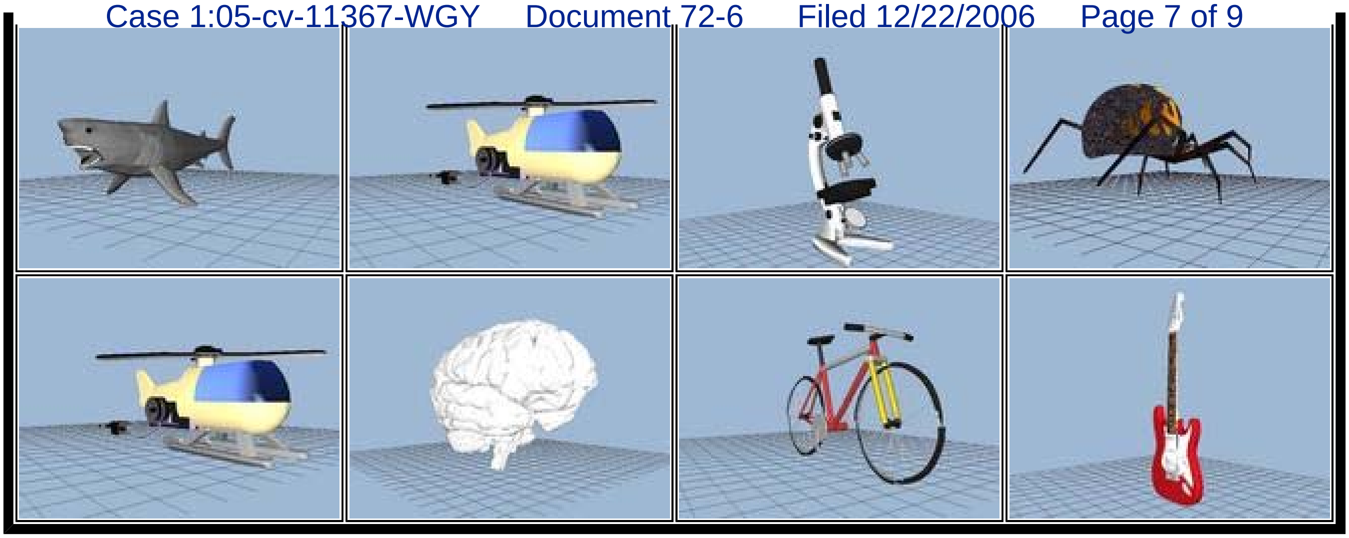
- **2D Sketches:**
  An alternative approach is to allow the user to draw one or more 2D shapes with a pixel paint program and then have the system match the resulting image(s) to 2D projections of 3D objects. For example, in the figures below, the user has drawn outline contours specifying a shape, and the system has returned a set of matching objects.



Princeton Shape Benchmark

- [The Princeton Shape Benchmark](#) provides a repository of 3D models and software tools for evaluating shape-based retrieval and analysis algorithms. The motivation is to promote the use of standardized data sets and evaluation methods for research in matching, classification, clustering, and recognition of 3D models. Researchers are encouraged to use these resources to produce comparisons of competing algorithms in future publications.

- The benchmark contains a database of 3D polygonal models collected from the World Wide Web. For each 3D model, there is a Object File Format (.off) file with the polygonal geometry of the model, an ASCII text file with information about the model (e.g., the URL from whence it came), and a JPEG image file with a thumbnail view of the model. Version 1 of the benchmark contains 1,814 models. [Source code](#) for parsing the files, viewing the models, and creating overview web pages is provided.



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Graphics & Geometry Group, CS Department, Princeton University

EXHIBIT 3

Image Database Indexing using a Combination of Invariant Shape and Color Descriptions *

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Abstract ***Image and video library applications are becoming increasingly popular. The increasing popularity calls for software tools to help the user query and retrieve database images efficiently and effectively. In this paper, we present a technique which combines shape and color descriptors for invariant, within-a-class retrieval of images from digital libraries. We demonstrate the technique on a real database containing airplane images of similar shape and query images that appear different from those in the database because of lighting and perspective. We were able to achieve a very high retrieval rate.***

Keywords: images, video, libraries, features

1 Introduction

Image and video library applications are becoming increasingly popular as witnessed by many national and international research initiatives in these areas, an exploding number of professional meetings devoted to image/video/multi-media, and the emergency of commercial companies and products. The advent of high-speed networks and inexpensive storage devices has enabled the construction of large electronic image and video archives and greatly facilitated their access on the Internet. In line with this, however, is the need for software tools to help the user query and retrieve database images efficiently and effectively.

Querying an image library can be difficult and one of the main difficulties lies in designing powerful features or descriptors to represent and organize images in a library. Many existing image database indexing and retrieval systems are only capable of *between-classes* retrieval (e.g., distinguishing fish from airplanes). However, these systems do not allow the user to retrieve images that are more specific. In other words, they are unable to perform *within-a-class* retrieval (e.g., distinguishing different types of airplanes or different species of fish). This is because the aggregate features adopted by many current systems (such as color histograms and low-ordered moments) capture only the general shape of a class and are not descriptive enough to distinguish objects within a particular class.

The within-a-class retrieval problem is further complicated if query images depicting objects, though belonging to the class of interest, may look different due to non-essential or incidental environment changes, such as rigid-body or articulated motion, shape deformation, and change in illumination and viewpoint. In this paper, we address the problem of *invariant, within-a-class* retrieval of images by using a combination of invariant shape and color descriptors. By analyzing the shape of the object's contour as well as the color and texture characteristics of the enclosed area, information from multiple sources is fused for a more robust description of an object's appearance. this places our technique at an advantage over most current approaches that exploit either geometric information or color information exclusively.

The analysis involves projecting the shape and color information onto basis functions of finite, local support (e.g., splines and wavelets). The projection coefficients, in general, are sensitive to changes induced by rigid motion, shape deformation, and change in illumination and perspective. We derive expressions by massaging these sets of projection coefficients to cancel out the environmental factors to achieve invariance of the descriptors. Based on these features, we have conducted preliminary experiments to recognize different types of airplanes (many of them having very similar shape) under varying illumination and

*Supported in part by a grant from the National Science Foundation, IRI-94-11330

viewing conditions and have achieved good recognition rates. We show that information fusion has helped to improve the accuracy in retrieval and shape discrimination.

2 Technical Description

In this section, we present the theoretical foundation of our image-derived, invariant shape and color features. Invariant features form a compact, intrinsic description of an object, and can be used to design retrieval and indexing algorithms that are potentially more efficient than, say, aspect-based approaches.

The search for invariant features (e.g., algebraic and projective invariants) is a classical problem in mathematics dating back to the 18th century. The need for invariant image descriptors has long been recognized in computer vision. Invariant features can be designed based on many different methods and made invariant to rigid-body motion, affine shape deformation, scene illumination, occlusion, and perspective projection. Invariants can be computed either globally, such is the case in invariants based on moments or Fourier transform coefficients, or based on local properties such as curvature and arc length. See [3, 4, 5] for survey and discussion on the subject of invariants.

As mentioned before, our invariant features are derived from a localized analysis of an object's shape and color. The basic idea is to project an object's exterior contour or interior region onto localized bases such as wavelets and splines. The coefficients are then normalized to eliminate changes induced by non-essential environmental factors such as viewpoint and illumination. We will illustrate the mathematical frameworks using a specific scenario where invariants for curves are sought. The particular basis functions used in the illustration will be the wavelet bases and spline functions. Interested readers are referred to [1] for more details.

Several implementation issues arise in this invariant framework which we will briefly discuss before describing the invariant expressions themselves. [1]

1. How are contours extracted?

Or stated slightly differently, how is the problem of segmentation (separating objects from background) addressed? Segmentation turns out to be an extremely difficult problem and, as fundamental a problem as segmentation is, there is no failproof solution. A "*perfect*" segmentation scheme is like the holy grail of low-level computer vision and a panacea to many high level vision problems as well.

We are not in search of this holy-grail, which, we believe, is untenable in the foreseeable future. In an image database application, the problem of object segmentation is simplified because

- Database images can usually be acquired under standard imaging conditions which allow the ingest and catalog operations to be automated or semi-automated. For example, to construct a database of airplane images, many books on civil and military aircrafts are available with standard front, side, and top views taken against a uniform or uncluttered background. (The above is also true for applications in botany and marine biology.) This allows the contours of the objects of interest to be extracted automatically or with the aid of standard tools such as the flood fill mask in Photoshop. Furthermore, the cataloging operations are usually done off-line and done only once. Hence, a semi-automated scheme will suffice.
- On the other hand, query images are usually taken under different lighting and viewing conditions. Objects of interest can be embedded deeply in cluttered background which makes their extraction difficult. However, we can enlist the help of the user to specify the object of interest instead of asking the system to attempt the impossible task of automated segmentation. A query-by-sketch or a "human-in-the-loop" type solution with an easy-to-use graphics interface and segmentation aids such as the flood fill mask is perfectly adequate here and does not impose undue burden on the user. This proved to be feasible in our experiments.

2. How are contours parameterized?

For a contour based description, a common frame of reference is usually needed that allows point correspondences to be established between two contours for comparison. The common frame of reference comprises a common starting point of traversal, a common direction of traversal, and a parameterization scheme that traverses to the corresponding points in the two contours at the same parameter setting. We will first discuss the parameter-

[1] A word on the notational convention: matrices and vectors will be represented by bold-face characters while scalar quantities by plain-face characters. 2D quantities will be in small letters while 3D and higher-dimensional quantities in capital letters. For example, coordinates (bold for vector quantities) of a 2D curve (small letter for 2D quantities) will be denoted by $\mathbf{c}$.

ization issue and then address the issues of point correspondence and traversal direction.

When defining a parameterized curve $\mathbf{c}(t) = [x(t), y(t)]^T$, most prefer the use of the intrinsic arc length parameter because of its simplicity and the fact that it is either invariant or transforms linearly in rigid-body motion and uniform scaling. However, under more general scenarios where shape deformation is allowed (e.g., deformation induced in an oblique view), intrinsic arc length parameter is no longer invariant. Such deformation can stretch and compress different portions of of an object's shape, and a parameterization based on intrinsic arc length will result in wrong point correspondence.

It is well known that many shape deformation and distortion resulting from imaging can be modeled as an affine transform, through which the intrinsic arc length is nonlinearly transformed [2]. An alternative parameterization is thus required. There are at least two possibilities. The first, called *affine arc length*, is defined [2] as: $\tau = \int_a^b \sqrt[3]{\dot{x}\ddot{y} - \ddot{x}\dot{y}}\ dt$ where $\dot{x}, \dot{y}$ are the first and $\ddot{x}, \ddot{y}$ are the second derivatives with respect to any parameter t (possibly the intrinsic arc length), and (a, b) is the path along a segment of the curve.

Another possibility [2] is to use the *enclosed area parameter*: $\sigma = \frac{1}{2}\int_a^b |x\dot{y} - y\dot{x}|\ dt$. One can interpret the enclosed area parameter as the area of the triangular region enclosed by the two line segments from the centroid of an object to two points a and b on the contour. It can be shown that both these parameters transform linearly under a general affine transform [2]. Hence, they can easily be made absolutely invariant by normalizing them with respect to the total affine arc length or the total enclosed area of the whole contour, respectively. We use these parameterizations in our experiments.

3. How are identical traversal direction and starting point guaranteed?

It will be shown that the *invariant signatures* (to be defined later) of two contours are phase-shifted versions of each other when only the starting point of traversal differs. Furthermore, the same contour parameterized in opposite directions produces invariant signatures that are flipped and inverted images of each other. Hence, a match can be chosen that maximizes certain cross-correlation relations between the two signatures.

Allowing an arbitrary change of origin and traversal direction, together with the use of an affine invariant parameterization, imply that **no point correspondence is required in computing our invariants.**

Now we are ready to introduce the invariant expressions themselves. Our invariants framework is very general and considers variation in an object's image induced by rigid-body motion, affine deformation, and changes in parameterization, scene illumination, and viewpoint. Each formulation can be used alone, or in conjunction with others. Due to the page limitation, we can only give a brief discussion of the invariants under rigid-body and affine transform and summarize the invariant expressions under change of illumination and viewpoint. Interested readers are referred to [1] for more details.

Invariants under Rigid-Body Motion and Affine Transform Consider a 2D curve, $\mathbf{c}(t) = [x(t), y(t)]^T$ where t denotes a parameterization which is invariant under affine transform (as described above), and its expansion onto the wavelet basis $\psi_{a,b} = \frac{1}{\sqrt{a}} g(\frac{t-b}{a})$ (where $g(t)$ is the mother wavelet) as $\mathbf{u}_{a,b} = \int \mathbf{c}(t)\psi_{a,b} dt$. If the curve is allowed a general affine transform with the possibility of being traversed from a different starting point and along an opposite direction, then the transformed curve is denoted by: $\mathbf{c}'(t) = \mathbf{m}\mathbf{c}(t') + \mathbf{t} = \mathbf{m}\mathbf{c}(\pm t + t_0) + \mathbf{t}$, where $\mathbf{m}$ is any nonsingular 2×2 matrix, $\mathbf{t}$ represents the translational motion, t_0 represents a change of the origin in traversal, and $\pm$ represents the possibility of traversing the curve either counterclockwise or clockwise:

$$\begin{aligned}
\mathbf{u}'_{a,b} &= \int \mathbf{c}'\psi_{a,b} dt \\
&= \int (\mathbf{m}\mathbf{c}(\pm t + t_0) + \mathbf{t})\psi_{a,b} dt \\
&= \mathbf{m}\int \mathbf{c}(t')\frac{1}{\sqrt{a}} g(\frac{\mp(t'-t_0)-b}{a})dt' + \int \mathbf{t}\psi_{a,b} dt \\
&= \mathbf{m}\int \mathbf{c}(t')\frac{1}{\sqrt{a}} g(\frac{t'-(\pm b+t_0)}{a})dt' \\
&= \mathbf{m}\int \mathbf{c}(t')\psi(t')_{a,\pm b+t_0} dt' \\
&= \mathbf{m}\mathbf{u}_{a,\pm b+t_0} \ .
\end{aligned} \tag{1}$$

Note that we use the wavelet property $\int \psi_{a,b} dt = 0$ to simplify the second term in Eq. 1. If $\mathbf{m}$ represents a rotation (or the affine transform is a rigid-body motion of a translation plus a rotation), it is easily seen that an **invariant expression** (this is just one of many possibilities) can be derived using the ratio expression

$$\frac{|\mathbf{u}'_{a,b}|}{|\mathbf{u}'_{c,d}|} = \frac{|\mathbf{m}\mathbf{u}_{a,\pm b+t_0}|}{|\mathbf{m}\mathbf{u}_{c,\pm d+t_0}|} = \frac{|\mathbf{u}_{a,\pm b+t_0}|}{|\mathbf{u}_{c,\pm d+t_0}|} \ , \tag{2}$$

which is a function of the scale a and the displacement b. If we fix the scale a, by taking the same

Scenarios	Invariant expressions
Rigid-body motion (using spline basis)	$\frac{\lvert \mathbf{u}_{a,b}-\mathbf{u}_{c,d} \rvert}{\lvert \mathbf{u}_{e,f}-\mathbf{u}_{g,h} \rvert}$
Affine transform (using wavelet basis)	$\frac{\begin{vmatrix} \mathbf{u_{a,b}} & \mathbf{u_{c,d}} \end{vmatrix}}{\begin{vmatrix} \mathbf{u_{e,f}} & \mathbf{u_{g,h}} \end{vmatrix}}$
Affine transform (using spline basis)	$\frac{\begin{vmatrix} \mathbf{u_{a,b}} & \mathbf{u_{c,d}} & \mathbf{u_{e,f}} \\ 1 & 1 & 1 \end{vmatrix}}{\begin{vmatrix} \mathbf{u_{g,h}} & \mathbf{u_{i,j}} & \mathbf{u_{k,l}} \\ 1 & 1 & 1 \end{vmatrix}}$
Perspective transform (using *rational spline basis* R)	$\int_t (\mathbf{d}(t) - \sum_i \mathbf{p}_i R_{i,k}(t))^2 dt$ where $\mathbf{d}(t)$ is the observed image curve, and $\sum_i \mathbf{p}_i R_{i,k}(t)$ is the database curve in rational spline form.
Change of illumination	$\frac{\lvert [\mathbf{u}_{a_1,b_1}\mathbf{u}_{a_2,b_2}\cdots\mathbf{u}_{a_k,b_k}]^T[\mathbf{u}_{a_1,b_1}\mathbf{u}_{a_2,b_2}\cdots\mathbf{u}_{a_k,b_k}] \rvert}{\lvert [\mathbf{u}_{c_1,d_1}\mathbf{u}_{c_2,d_2}\cdots\mathbf{u}_{c_k,d_k}]^T[\mathbf{u}_{c_1,d_1}\mathbf{u}_{c_2,d_2}\cdots\mathbf{u}_{c_k,d_k}] \rvert}$

Table 1: Other invariant measures

number of sample points along each curve, we can construct a function $f_a(x)$ which we call the **invariant signature** of an object as:

$$
\begin{aligned}
f_a(x) &= \frac{|\mathbf{u}_{a,x}|}{|\mathbf{u}_{a,x+x_0}|} \quad \text{and} \\
f'_a(x) &= \frac{|\mathbf{u}'_{a,x}|}{|\mathbf{u}'_{a,x+x_0}|} = \frac{|\mathbf{m}\mathbf{u}_{a,\pm x+t_0}|}{|\mathbf{m}\mathbf{u}_{a,\pm(x+x_0)+t_0}|} \\
&= \frac{|\mathbf{u}_{a,\pm x+t_0}|}{|\mathbf{u}_{a,\pm(x+x_0)+t_0}|} ,
\end{aligned}
\tag{3}
$$

where x_0 represents a constant value separating the two indices. Then it is easily verified that when the direction of traversal is the same for both contours, $f'_a(x) = \frac{|\mathbf{u}_{a,x+t_0}|}{|\mathbf{u}_{a,x+x_0+t_0}|} = f_a(x + t_0)$. If the directions are opposite, then $f'_a(x) = \frac{|\mathbf{u}_{a,-x+t_0}|}{|\mathbf{u}_{a,-x-x_0+t_0}|} = \frac{1}{f_a(-x-x_0+t_0)}$. As the correlation coefficient of two signals is defined as

$$
R_{f(x)g(x)}(\tau) = \frac{\int f(x)g(x+\tau)dx}{\|f\| \cdot \|g\|} ,
$$

we define the **invariant measure** $I_a(f, f')$ (or the similarity measure) between two objects as

$$
I_a(f, f') = max_{\tau,\tau'}\{R_{f_a(x)f'_a(x)}(\tau), R_{f_a(x)\frac{1}{f'_a(-x)}}(\tau')\} . \tag{4}
$$

It can be shown [1] that the invariant measure in Eq. 4 attains the maximum of 1 if two objects are identical, but differ in position, orientation, scale, and traversal direction and starting point. Due to the page limit, we will only summarize other invariant expressions in Table 1 without derivation. The entries shown in the table are the *invariant expressions* (similar to Eq. 2). The process of deriving *invariant signatures* (similar to Eq. 3) and *invariant measures* (similar to Eq. 4) are similar and will not be repeated here.

3 Experimental Results

In the following, we will present some preliminary results. The purpose is to provide a proof-of-concept demonstration and to discover research issues that need be addressed for a large-scale implementation and testing. Hence, the database used is of a relatively small size.

The scenario is that of a digital image database comprises a collection of sixteen airplanes in canonical (top) view (Fig. 1). The airplane contours were automatically extracted from the images and invariant shape and color signatures computed off-line. Eleven query images (Fig. 2) were photographed of these airplanes from different viewpoints and under varying illumination. The airplanes in the query images were extracted using a semi-automated process with user assistance. Even though the image database is relatively small, it contains objects of very similar appearance (e.g., models 5 and 6, and models 3, 7, and 14). Furthermore, the query images (Fig. 2) differ greatly from the database images due to large changes in perspective and illumination. This is in contrast with many digital image library retrieval schemes which can perform only between-classes (e.g., airplanes vs. cars) retrievals with small changes in imaging condition.

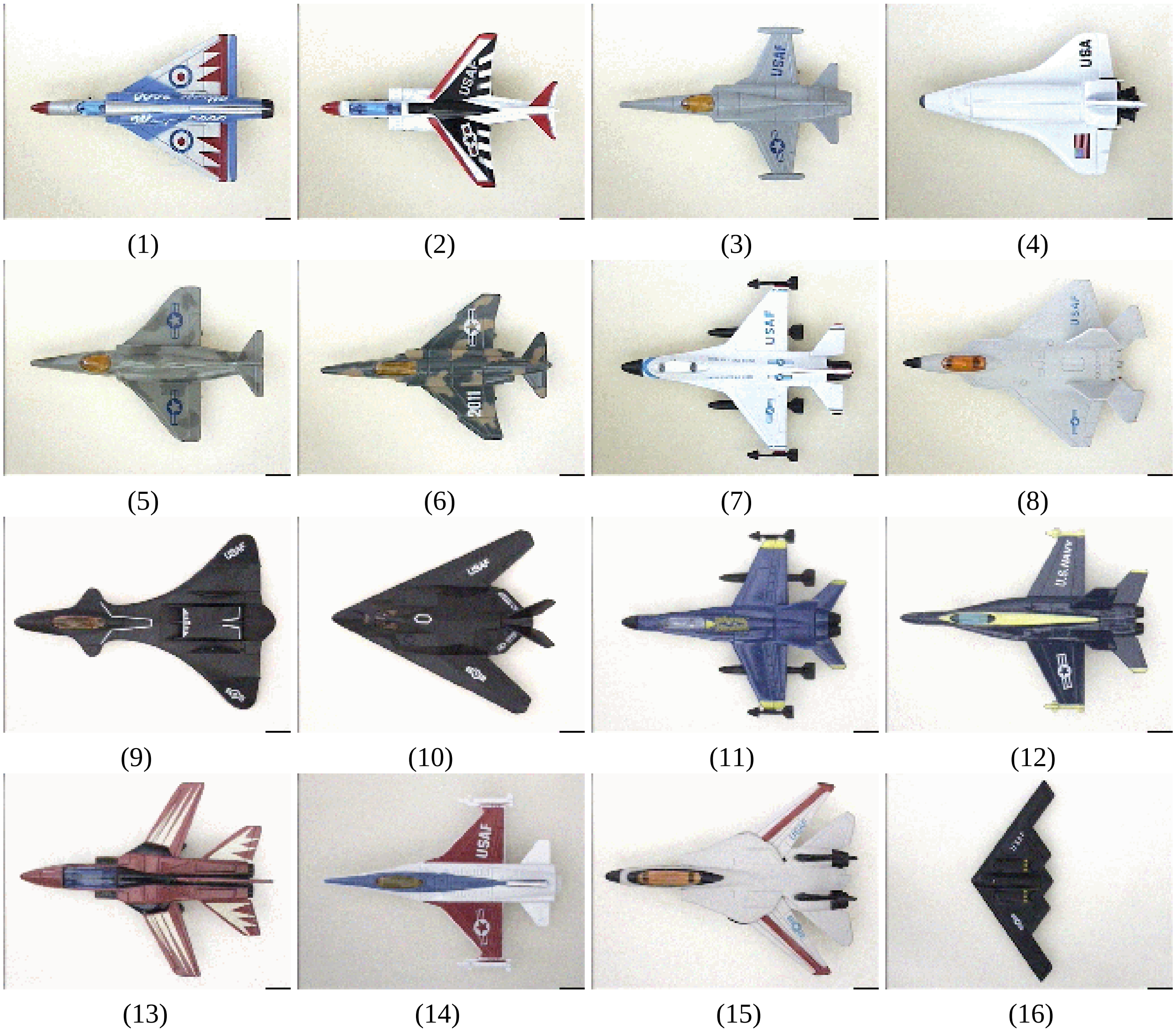

Figure 1: A database of airplane models.

We used a two-stage approach in information fusion. Features invariant to affine deformation and perspective projection were first used to match the silhouette of the query airplane with the silhouettes of those in the database. We then employed the illumination invariants computed on objects' interior to disambiguate among models with similar shape but different colors. **The results show that we were able to achieve 100% accuracy using our invariants formulation for a database comprising very similar models, presented with query images of large perspective shape distortion and change in illumination.**

Table 2 shows the performance of using affine and perspective invariants for shape matching under a large change of viewpoint. For each query image (A through K), the affine and perspective invariant signatures were computed, and compared with the signatures of all models in the database. Correlation coefficients as described in Sec. 2 were used to determine the similarity between each pair of signatures. Each row in Table 2 refers to a query image. Each of the ten columns represents the rank given to each airplane model from the database (shown in parentheses). The columns are ordered from left to right, with the leftmost column being the best match found. Only the top ten matches are shown. The values (not in parentheses) are the correlation coefficients. Entries printed in boldface are the expected (correct) matches.

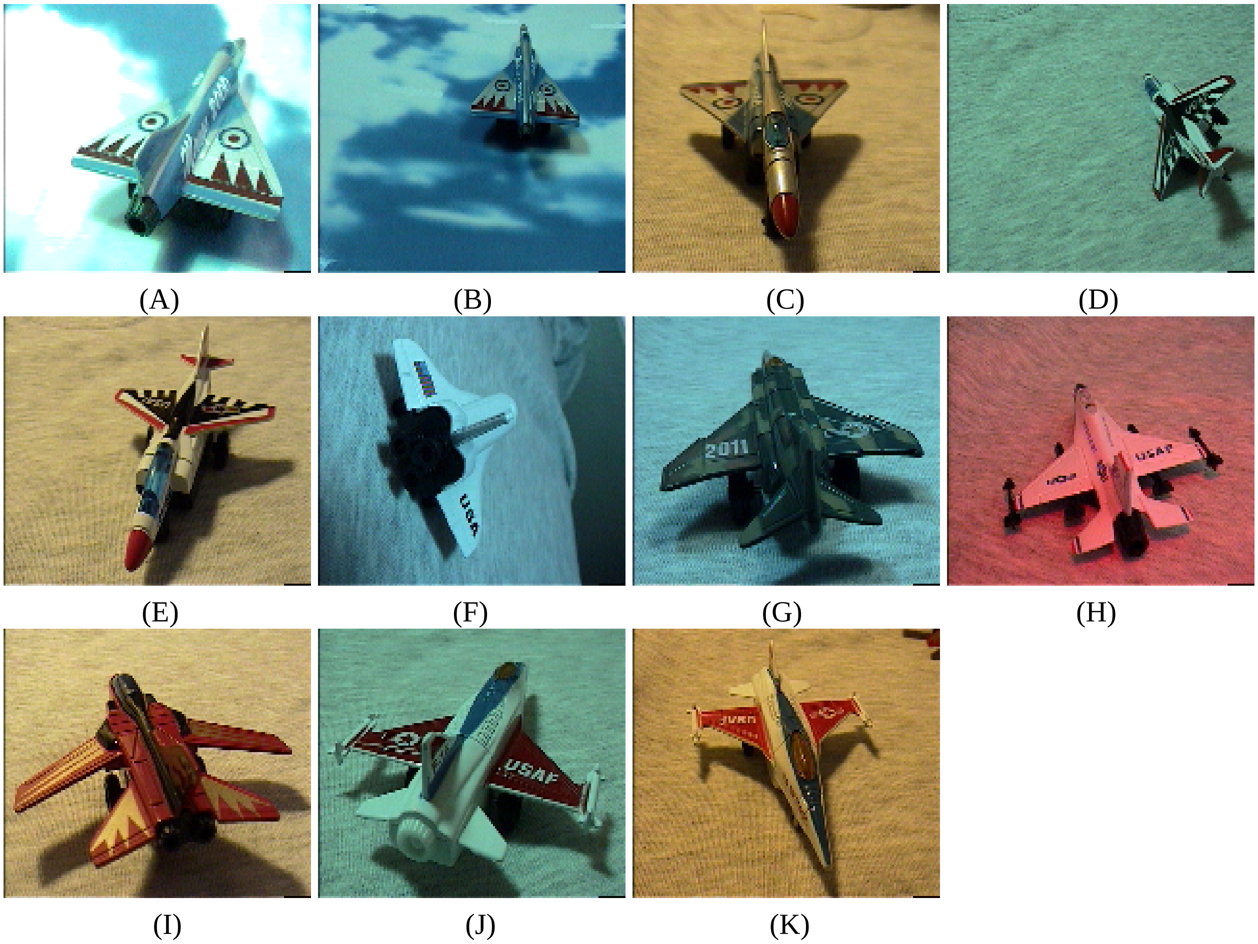

Figure 2: The same airplanes in varying poses and illumination.

As can be seen, all query images were identified correctly. Fig. 3 shows a sample result. The leftmost image is the query image. The top three matches are in the next three columns—the query image (solid) and estimated image (dashed, using perspective invariants) with the corresponding database model are shown.

For this experiment, *all* query images were correctly matched with the models from the database, using affine and perspective invariants. However, the error values of the top two matches for, say, airplane K were very close to each other. This is because the top two matches have similar shapes and both are similar to the query image. The confidence in the selected matches can be strengthened by testing whether the interior regions of the objects are also consistent. Illumination invariants readily applies here.

For illumination invariants, a characteristic curve was uniquely defined on the surface of each airplane model in the database (performed off-line), so that its superimposition over the model emphasizes important (or interesting) color patterns in the image. Our perspective invariants scheme computed the transformation parameters that best match the two given contours. The same parameters were used to transform the characteristic curve defined for each model to its assumed pose in the query image. Hence, the colors defined by the characteristic curve in the model should match the colors defined by the transformed curve in the query image (except for changes due to illumination). Illumination invariant signatures for the query images were then computed, and compared with the signatures stored in the database using Eq. 4.

We show one result of illumination invariants where the (perspective invariant) errors of the 1^{st}

	Rank (using affine and perspective invariants)									
Image	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}	7^{th}	8^{th}	9^{th}	10^{th}
A	**(1) 0.8792**	(9) 0.7210	(4) 0.6161	(6) 0.4967	(5) 0.4663	(10) 0.4578	(2) 0.4030	(7) 0.3248	(11) 0.2443	(14) 0.2388
B	**(1) 0.9527**	(9) 0.8532	(10) 0.7666	(4) 0.7479	(6) 0.6630	(2) 0.6103	(5) 0.5943	(15) 0.5364	(16) 0.4756	(7) 0.4576
C	**(1) 0.8538**	(4) 0.6806	(2) 0.6521	(9) 0.6016	(6) 0.5623	(5) 0.5353	(10) 0.4446	(14) 0.3359	(7) 0.3095	(11) 0.2386
D	**(2) 0.9283**	(6) 0.9002	(5) 0.8962	(4) 0.8177	(13) 0.8097	(14) 0.7801	(1) 0.7730	(7) 0.7663	(3) 0.7502	(12) 0.7439
E	**(2) 0.9228**	(5) 0.7747	(6) 0.7622	(14) 0.6975	(12) 0.6167	(4) 0.6167	(3) 0.6146	(13) 0.5902	(7) 0.5704	(15) 0.4813
F	**(4) 0.6369**	(1) 0.6002	(9) 0.5810	(6) 0.5291	(10) 0.5205	(14) 0.5056	(5) 0.4486	(11) 0.4283	(2) 0.4036	(7) 0.3946
G	**(6) 0.8254**	(13) 0.7293	(5) 0.7026	(4) 0.6616	(2) 0.6460	(14) 0.6396	(12) 0.6287	(3) 0.6035	(1) 0.5930	(7) 0.5638
H	**(7) 0.8747**	(14) 0.8552	(3) 0.8398	(11) 0.8226	(13) 0.7848	(6) 0.7668	(12) 0.7663	(5) 0.7282	(2) 0.7007	(4) 0.6980
I	**(13) 0.8609**	(6) 0.6890	(3) 0.6563	(14) 0.6468	(12) 0.6343	(5) 0.6107	(7) 0.5916	(2) 0.5849	(15) 0.5775	(1) 0.5516
J	**(14) 0.8815**	(3) 0.8017	(12) 0.7564	(13) 0.7512	(7) 0.7055	(11) 0.6805	(6) 0.6501	(4) 0.6346	(5) 0.5838	(15) 0.5711
K	**(14) 0.8779**	(3) 0.8558	(7) 0.7623	(13) 0.7272	(12) 0.7270	(6) 0.7235	(11) 0.7209	(2) 0.6503	(5) 0.6191	(4) 0.5459

Table 2: Top ten matches between each query image and database models, using affine and perspective invariants. Numbers in parentheses indicate the airplane model selected. The value beneath it is the similarity measure between the selected image and query image. The correct airplane model is in boldface. Each row corresponds to a query image. The columns are arranged left to right, from the best match to worse.

and 2^{nd} best matches differ by a small amount (see Table 2); in this case, query image K. Figs. 4 (a) and (d) show the characteristic curves (the zigzag lines) superimposed over the images of models 14 and 3. The transformed characteristic curves, shown in (b) and (e), is superimposed over the query image K, using parameters estimated from perspective invariants. Finally, (c) and (f) show the illumination invariant signatures. Clearly, the signatures in (c) is much more consistent, which reinforces the results from shape invariants.

4 The Concluding Remarks

We present a technique where shape/color information from interior/contour points is used to describe an imaged object for database retrieval. The technique is superior in that it tolerates changes in appearance induced by incidental environmental factors and is powerful enough for within-a-class retrieval.

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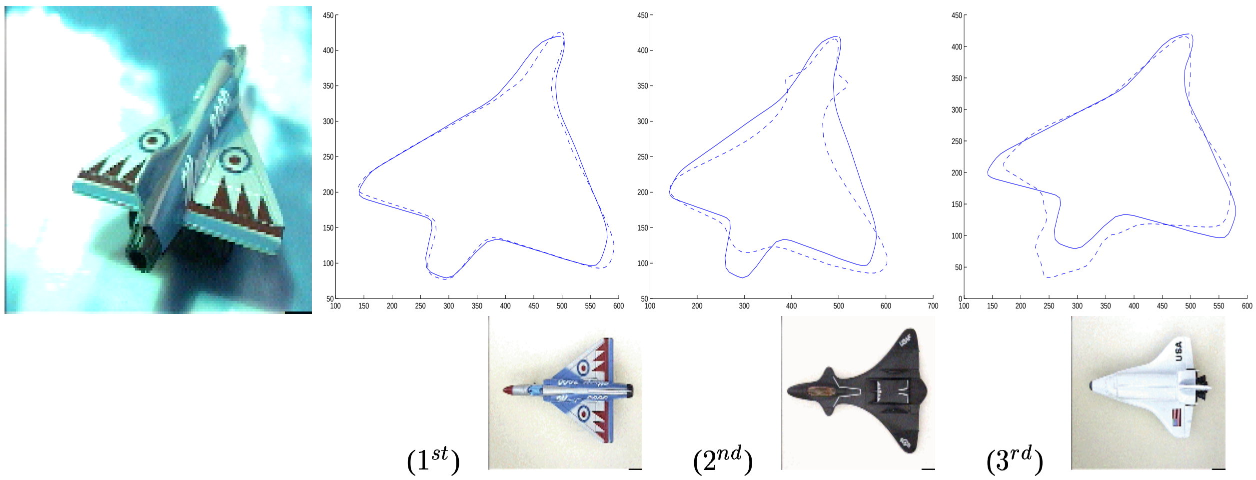
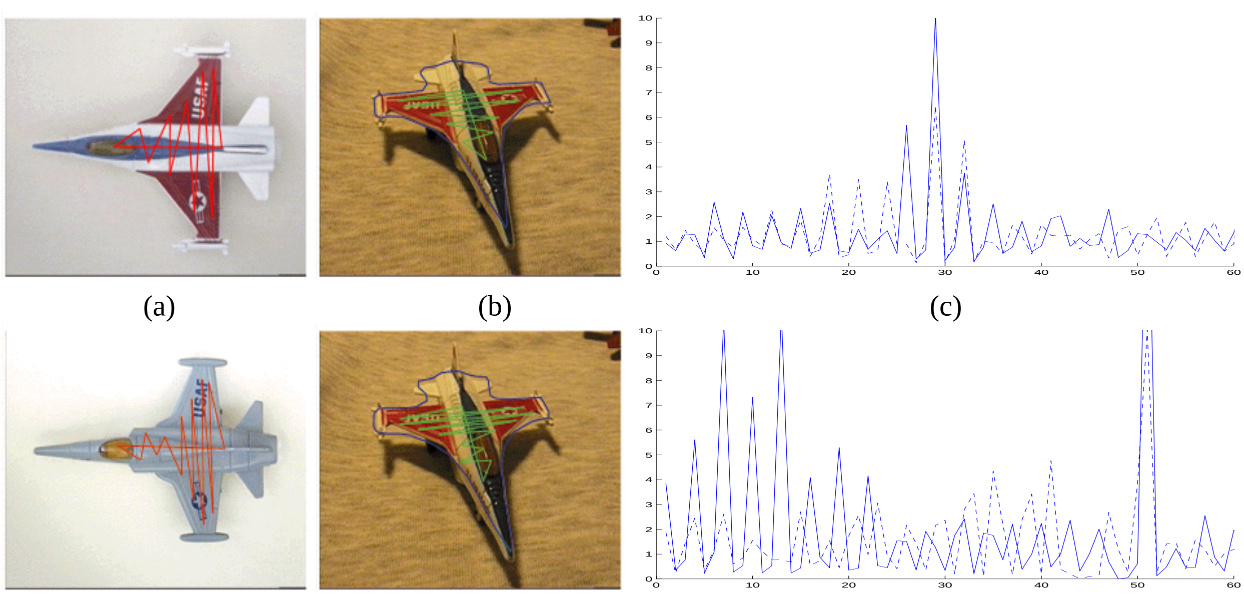


(1^{st}) (2^{nd}) (3^{rd})

Figure 3: Query image A, with the top three matches from the database, using perspective invariants. (Solid for the query image, dashed for the estimated image using perspective invariants.)



(a) (b) (c)

(d) (e) (f)

Figure 4: (a),(d) Airplane models with the characteristic curves superimposed, (b),(e) query image with the transformed characteristic curves superimposed, and (c),(f) illumination invariant signatures for query image K (solid) and for models 14 and 3 (dashed).

EXHIBIT 4

Robust Airborne Combat Identification using Scale-Invariant Spatial and Spectral Electro-Optic Signatures
Navy SBIR FY2005.2

Sol No.:	Navy SBIR FY2005.2
Topic No.:	N05-111
Topic Title:	Robust Airborne Combat Identification using Scale-Invariant Spatial and Spectral Electro-Optic Signatures
Proposal No.:	N052-111-0628
Firm:	Toyon Research Corp. Suite A 75 Aero Camino Goleta, California 93117-3139
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Abstract:	Electro-optic (EO) imagery provides a rich source of information for feature-based target combat identification (CID). Yet, variable operating conditions, including sensor range, depression angle, and angle of approach, as well as target illumination and degree of occlusion, have so far prevented the development and effective deployment of a complete solution for real-time airborne CID. While much attention has been devoted to discovering target features which are invariant to orientation and affine view transformation, the resulting features have proven to be insufficiently discriminatory for large model databases. To address these and other challenges, we propose the use of scale- and affine transformation-invariant spatial and intensity features, combined with color/spectral histogram features, for robust, high-performance CID. Furthermore, we show how real-time airborne processing capability can be achieved through efficient candidate target segmentation followed by a hierarchical classification structure. This framework ensures that the most computationally demanding operations are only performed for a small number of most likely candidate target matches. Throughout, we show how storage and bandwidth requirements can be minimized, to enable deployment of the complete CID system on the F/A-18E/F and a variety of other platforms, leading to reduced operator workload and improved combat effectiveness.
Benefits:	The successful completion of this research will result in the development of algorithms for robust airborne CID. These algorithms will enable reduced operator workload and provide future military commanders with the ability to locate and identify ground, air, and maritime targets in a rapid and effective manner, yielding a key advantage on the battlefield. Additionally, our algorithms apply to many computer vision and pattern-matching problems of commercial and government interest, such as facility protection, rescue services, and medical diagnostics.

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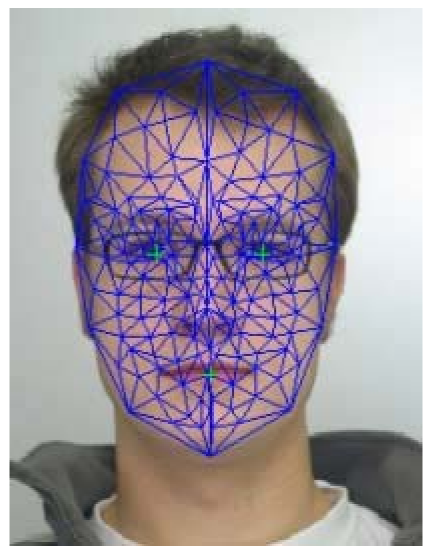
EXHIBIT 5

New Facial Recognition Software Fights Identity Fraud

April 1, 2005

Every day in Kentucky, 4,000 citizens get a new or renewed driver's license. Since 2002, those licenses have been digitized, featuring a digital image and digital data. Kentucky's upgrade to a digitized license has been the work of the Kentucky Transportation Cabinet and Viisage, a vendor delivering advanced technology identity solutions for governments, law enforcement agencies and businesses concerned with enhancing security and protecting personal privacy. "Using biometrics in the licensing process provides a valuable new tool to help determine if a person has multiple identities in the system, helps us investigate identity theft cases and further assists law enforcement agencies", commented Roy Mundy, Commissioner of the Department of Vehicle Regulation.

In March, Viisage conducted training for the Kentucky Transportation Cabinet's Division of Driver Licensing and the Kentucky State Police (KSP) on an upgraded version of their facial recognition software package. The software, called FaceEXPLORER, currently manages more than 3.9 million images from the Kentucky driver's license system. All the information is stored in a secure database.



Before the move to the digitized license, searching for a single case of an individual with multiple identities in the driver's license system could take up to 47 days. FaceEXPLORER can search the entire 3.9 million images in just 15 seconds, comparing the selected image to the closest match using a method of scoring based on similar facial characteristics. The software uses a highly complex algorithm to digitize the features on a person's face to a numeric value. That numeric value allows a computer system to quickly analyze the images. While the technology is rapidly improving, human intervention is still a key component to identify a match.

Those working on the new system quickly point out that the image database is used as an internal investigation tool only, not for line-ups or identifying the public. Kentucky's driver licenses are already recognized as one of the best in the nation. The move to using biometrics in the licensing process places Kentucky as a national leader.

"This state of the art technology provides a tremendous investigative resource for law enforcement officers across the state and we appreciate the Kentucky Transportation Cabinet's partnership on this project," stated Major Alecia Webb-Edgington, chief information officer for the Kentucky State Police.

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